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(54) Digital reading device for facsimile apparatus.

(57) The charge coupled device (23) provides serialised signals from a line of a document to an A/D converter (28). In order to compensate for factors such as non-uniformity of lighting, non-uniformity of CCD cell response and variations with time, a reference strip is read before each reading of a document and the corresponding digital values are stored in a RAM (31). Thereafter the stored values and the values read from each line of the document are compared to provide compensated values to a half tone generator (42) which codes the output. In particular, the comparison is effected by means of an ROM (32) addressed in part by the digital value derived from a pixel in the line of the document and in part by the digital value stored in the RAM (31) from the corresponding pixel in the reference strip. The values held in the ROM (32) correspond to the ratio between the addressing values. The ROM (32) may have modules for each of a plurality of different colours selected by a multiplexer (41) in correspondence with the selection of a filter determining the scanning colour. The reference strip is scanned through each filter before the document is scanned to determine the values in the RAM (31).

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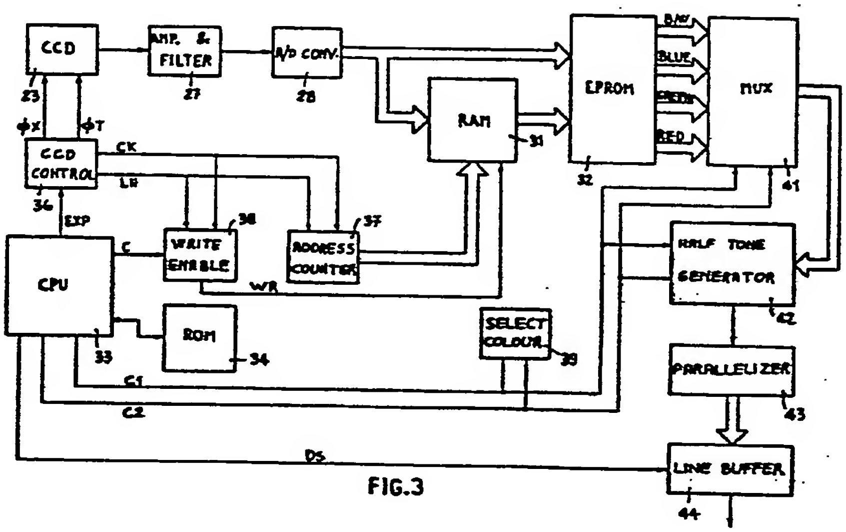
CCD
AMP. & FILTER
A/D CONV.
EPROM
MUX
RAM
CCD CONTROL
CK
LH
EXP
WRITE ENABLE
ADDRESS COUNTER
CPU
ROM
WR
SELECT COLOUR
HALF TONE GENERATOR
PARALLELIZER
LINE BUFFER
B/W
BLUE
GREEN
RED
C
C1
C2
DS
ϕX
ϕT
23
27
28
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32
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36
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44

FIG.3

DIGITAL READING DEVICE FOR FACSIMILE APPARATUS

The present invention refers to a digital reading device for facsimile apparatus, as defined in the preamble of claim 1.

In known apparatus of the aforesaid type, a given pixel of an image generates a signal whose intensity depends on the position along the image line of the original image point in the document, because of the different effect along the line of the means for directing the image on to the reading elements, the state of the illumination lamps, the variation in the time of response of the individual reading elements and the different response by one reading element to the other.

The object of the invention is to provide a reading device in which the amplitude of the reading signal is compensated, eliminating the effect of the variations in response of the said elements to a pixel of determined intensity due to decay of response through time and variation with position. The object problem is met by the device according to the invention, defined by the characterising part of claim 1.

The invention will be described in more detail, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a section of a schematic representation of a facsimile apparatus, incorporating a digital reading device embodying the invention.

Fig 2 is a plan of the apparatus along the line II-II of Fig 1; and

Fig 3 is a block diagram of the circuit for generating the signals of the reading device.

With reference to Fig 1, a transparent support plate 10 for a document 11 (Fig 2) to be read is fixed and is covered with a hinged cover 12 (Fig 1), suitable for holding the document 11 against the plate 10. Adjacent to the cover 12 is placed a keyboard 13 for control of the digital reader. This includes two fluorescent lamps 14, carried by a first carriage 16 moving transversely to explore the whole length of the document. The lamps 14 are selected in such a way as to supply collectively a substantially constant distribution of spectral energy versus wavelength in the field of

vision. As an example two lamps of the company Toshiba have been selected, one lamp 14 being of blue colour and the other of white colour with cold light, designated EDCW by Toshiba. The carriage 16 carries a mirror 17 inclined at 45°, so as to reflect the image of the elementary line of the document in a plane parallel to the document itself, as indicated by the broken line in Fig 1. The reader comprises also a second carriage 18 carrying a pair of mirrors 19 and 21 inclined 45° in opposite directions, so as to reflect the optical beam 180° towards an objective 22. This focuses the beam on to a series of reading elements constituted by cells of a charge coupled device 23 (CCD).

In order to allow the reading of images in colour, the optical beam can be filtered by a colour filter selected from a number of filters carried by a disc 24. This can be rotated by a stepping electric motor 26 in order to select from one time to the next the required filter. In particular the disc 24 comprises position without a filter for reading in black and white and three positions with red, green and blue filters for the reading of the respective colours. The cells of the CCD 23 are so spaced that each element can receive the light reflected by a small area of the document, called a pixel. The number of pixels per mm, generally between 3 and 12, determines the horizontal resolution of the reading device. The number of lines per mm read on the document on the other hand determines the vertical resolution of the reader. As an example the device may comprises a CCD 23 with 2048 cells, by means of which a 210 mm line is read with a resolution of 10 points/mm. As is known, the cells of the CCD 23 generate electrical signals corresponding to the intensity of light received, which after being serialized and then filtered and amplified by a circuit 27 (Fig 3) are sent to an analogue-digital converter 28 having for example a resolution of 6 bits, through which 64 levels of amplitude of reading signal can be identified. In particular the converter 28 is of the fast type, known as a flash A/D converter.

The digital signals can be coded, transmitted, stored and/or reproduced on paper. The ideal conditions for a correct reading would require a light source 14 (Fig 1) which is homogeneous along the line, an objective 22 devoid of losses at the edges, a constant

reflectance of the mirrors 17, 19 and 21 and a perfect homogeneity of response of the different cells of the CCD 23.

In reality the effect of the CCD 23 on a document of A4 format, with an objective 22 of 50 mm and a 2.8 f aperture, reduces by half the response signal at the edges of the line compared with the response which the same pixel would give at the centre of the line. With an aperture of 5.6 the reduction of the edges is about 30%, and in combination with the reduction due to dirty lamps about 50%. The non-homogeneity of the cells of the CCD 23 can lead to a variation of the signal of ± 10%, while dust deposition on the mirrors 17, 19 and 21 and the ageing of the lamps 14 cause variations in time, (although these variations are homogeneous along the length of the line).

According to the preferred embodiment of the invention on the plate 10 (Fig 2), in a position adjacent to the upper edge of the document 11, there is fixed a sample strip 29 of white colour, which constitutes the calibrated background of the original and is suitable for being read by the CCD 23 as a sample line before every reading of the document 11. The reading device comprises a read/write memory (RAM) 31 (Fig 3), to store the signals obtained in a preliminary reading of the sample strip 29, and means for comparison comprising a programmable read only memory (EPROM) 32 to compare the reading signals of the individual elementary lines of the document 11 with the signals stored in the RAM 31. Therefore the RAM 31 has a capacity of at least 2X6K bits. The reading device comprises a central processing unit (CPU)33 with a microprocessor, which when it receives a command for reading the document 11, generated by the keyboard 13, executes a programme recorded in a read only memory (ROM) 34.

The CPU 33 controls a circuit 36 for controlling the CCD 23, via a logic signal EXP corresponding to the duration of the enablement of the CCD for reading the document. In particular the circuit 36, in response to the logic signal EXP, generates an analogue signal ØX, which determines the duration of the enablement of the CCD 23, and a timing signal ØT, which determines the serialisation of the signals generated by the CCD 23, to be sent to the circuit 27.

The circuit 36 also generates a logic signal LN at every elementary line read and a logic signal CK at every pixel signal sent by the CCD 23 to the circuit 27. These two signals are sent to a counter 37, whose capacity is equal to the number of cells of the CCD 23 and hence to the number of pixels of an elementary line. The counter 37 thus indicates the position of the pixel whose signal is sent to the circuit 27. The output of the counter 37 addresses the successive locations of the RAM 31 in which the signals provided by the converter 28 are to be written or from which the signals stored there are to be read. The CPU 33 also generates, at the beginning of the reading routine given by the ROM 34, a signal C for a compensation command, which controls a circuit 38 for enablement of writing in the RAM 31. This circuit is further controlled by the signals LN and CK so as to emit the write-enable signal WR during the reading of the sample strip 29 (Fig 2). Thus the signals of this reading, emitted by the converter 28 (Fig 3), are recorded in the RAM 31 at the addresses given by the counter 37. On the other hand during the reading of the successive lines of the document 11, the signals emitted by the converter 28 are no longer stored by the RAM 31 and the counter 37 only addresses the cells of RAM 31 for reading from one line to the next.

The CPU further provides two signals C1 and C2 indicative of the colour of the filter, according to the following table:

C1	0	1	0	1
C2	0	0	1	1
COLOUR	B/W	RED	GREEN	BLUE

The signals C1 and C2 control a circuit 39 for selection of the filter; this circuit controls the rotation of the stepping motor 26 (Fig 1) in a manner known per se.

The EPROM 32 (Fig 3) is constituted by four modules associated with the four colours defined before. The four modules are addressed in parallel with 12 bits, six of which are supplied by the converter 28 in the direct reading of each pixel of the lines of the document 11, while the other six are supplied by the reading of the

RAM 31 at the address given by the counter 37, whereby these represent the signals given by the converter 28 in the reading of the corresponding pixel of the sample line.

In each module of the EPROM 32, at each address there is recorded in advance a 4-bit value proprotional to the ratio between the direct reading signal of a pixel and that recorded in the RAM 31 in the preliminary reading of the corresponding pixel of the sample strip 29. In particular the value recorded in the EPROM 32 is obtained by multiplying a number equal to the desired level number for the amplitude of the reading signal by the ratio between the value of the direct reading expressed by the six address bits supplied by the converter 28 and the value of the preliminary reading expressed by the six address bits supplied by the RAM 31. By recording this 4-bit value in the EPROM 32, it is possible to obtain directly the values of 16 levels of amplitude of the signal of the pixel read in the line of the document, basically compared with the signal of the pixel read in the sample line.

In other words on each module of the EPROM 32 there is constructed a true andd proper table of compensated values of reflectance compared with an address formed by six pre-stored bits in the RAM 31 and by six bits relating to the immediate reading of the pixels of the document. These values represent therefore the signals of the pixels compensated in amplitude for all the deteriorations of these occurring with time and with transverse location, through non-homogeneity of the lighting of the original, through dust deposition on the mirrors, through loss at the edges of the objective and through the non-homogeneity of the cells of the CCD.

The four modules of the EPROM 32 permit the adoption of different compensations for the three primary colours and for black. The values thus address on the four modules of the EPROM 32 are sent to a multiplexer 41, which under the control of the two signals C1 and C2 sends to a circuit 42 for coding greys of half tones only those relating to the colour selected by these signals.

The circuit 42 is also organised in four modules, one for each colour, selectable by the same signals C1 and C2. For each value given by the four bits of the multiplexer 41, the circuit 42 selects

a corresponding sequence of bits indicative of the white and coloured points, to represent the corresponding value of the half tone, in a manner in itself known.

The signals generated by the circuit 42 are then parallelised by a paralleliser 43 and are stored in a line buffer 44, under the control of an enablement signal DS emitted by the CPU 33 only when the scanning of the document 11 is effected. From the buffer 44 the stored signals are then taken for compression and subsequent storage in a mass or transmission memory to a distant station, or for controlling a device for reproduction of the image read.

It must be noted that during the reading of the sample line the EPROM 32 also supplies the four bits recorded at the address represented by two equal groups of six bits. Since, however, the CPU 33 does not emit the signal DS, these values are not stored in the buffer 44.

The programme recorded in the ROM 34 comprises a routine for reading in black and white and a routine for reading in colour. The two routines are selected by means of the keyboard 13. The routine for reading in black and white makes the device execute a single reading cycle, in which the corresponding white position of the filter 24 is selected. At the beginning the sample line 29 (Fig 2) is read, which is stored in the RAM 31 (Fig 3). Immediately afterwards the lines of the document 11 are read one after the other, whose values are compensated in amplitude by the B/W module in the EPROM 32.

The routine for reading in colour on the other hand makes the device execute three successive cycles of reading of the document 11, making the CPU 33 generate successively the values of the signals C1 and C2 which indicate red, green and blue. For each colour the device, by means of the circuit 39, first selects the corresponding filter of the disc 24 (Fig 2). Then it reads with this filter the sample line 29, storing the signals in the RAM 31 (Fig 3). Finally it reads with the same filter the successive lines of the document 11 and, by means of the appropriate module of the EPROM 32, it suppleis the reading signals of the corresponding colour, compensated in amplitude.

It is understood that the device described can have various

modifications and improvements made to it within the scope of the claims. For example the EPROM 32 can be replaced by a ROM or by any circuit suitable for supplying in output numerical or analogue values, as a function of the result of the comparison between the signals obtained in the reading of the sample line and those obtained in the direct reading of the lines of the document. Furthermore, the value recorded corresponding to each address of the compensation memory (EPROM or ROM) can be multiplied by a factor K which takes account of the particular use of the signal, for example for a video or for a print-out according to a specific technology. In that case, whenever the utilisation of the signals of the device is changed, it is necessary to replace the compensation memory. In particular the device can be fitted with a number of compensation memories, automatically selectable as a function of the use of the signal chosen from time to time.

CLAIMS

1. A digital reading device for facsimile apparatus, comprising a light source (14) for illuminating the document to be read, means (17, 19, 21, 22) for directing the image of a line of the document thus illuminated on to a series of reading elements (23) for generating a series of response signals in response to the points read along the line, an A/D converter (28) operative on the response signals to provide digital signals, and means (42) for coding the intensity of the digital signals according to a half tone scale, characterised by means (31) for storing the signals obtained from the A/D converter (31) in a preliminary reading of a calibrated background (29), and comparison means (32) responsive to the signals obtained from the A/D converter (28) in the reading of the document and the signals thus stored, the coding means (42) effecting the coding of the intensity of the digital signals in response to the comparison means, whereby variation of the transfer function of the device with time and from pixel to pixel is compensated.

2. A device according to claim 1, wherein the said directing means comprise at least one mirror (17, 19, 21) and an objective (22) and the reading elements (23) comprise a series of cells of a charge coupled device (CCD), characterised in that the compensation compensates for the combined effects of the light source (14), the mirrors (17, 19, 21), the objective (22) and the CCD (23).

3. A device according to claim 1 or 2, characterised in that the calibrated background is constituted by a sample strip (29) arranged in a position adjacent to the document to be read, which is read by the reading elements (23) immediately before the reading of the document, the comparison means (32) effecting each time the comparison between the signals obtained by the A/D converter (28) in the reading of one line of the document with the signals stored in the reading of the sample strip (29).

4. A device according to claim 3, characterised in that the storing means (31) comprise a read-write memory and the comparison

means (32) comprise a read only memory at each address of which there is stored in advance a value corresponding to the compensated signal corresponding to the comparison.

5. A device according to claim 4, characterised in that the stored value is proportional to the ratio between the direct reading signal of a pixel and that recorded in the preliminary reading of the corresponding pixel of the sample strip.

6. A device according to claim 5, characterised in that the read only memory (32) is addressed in part the digital signals of a given pixel and in part by the digital signals stored in the read-write memory (31) in the preliminary reading of the corresponding pixel of the sample strip (29).

7. A device according to claim 6, characterised in that the value stored in the read only memory is obtained by multiplying a number equal to the number of the desired levels of grey by the ratio between the value of the direct reading and the value of the preliminary reading, expressed by the respective address signals.

8. A device according to any of claims 4 to 7, comprising a plurality of filters (24) for the reading of images in colour, characterised in that the preliminary reading is effected on the sample strip (29) with the same filter (24) with which the document is read, the said coding being effected in successive readings of the document, whereby the compensation is effected for all the colours.

9. A device according to claim 8, characterised in that the read only memory (32) comprises a series of modules each associated with a filter colour, the modules being addressed in parallel, and the output data being selected (41) on the basis of the chosen filter (24).

10. A device according to claim 7 and claim 8 or 9, in which the signals of grey can be used by a variety of graphic appartuses, characterised in that a plurality of read only memories (32) are

associated with the different apparatuses and are selectable individually for operation, the values stored in each read only memory being multiplied by a factor corresponding to the associated graphic apparatus.

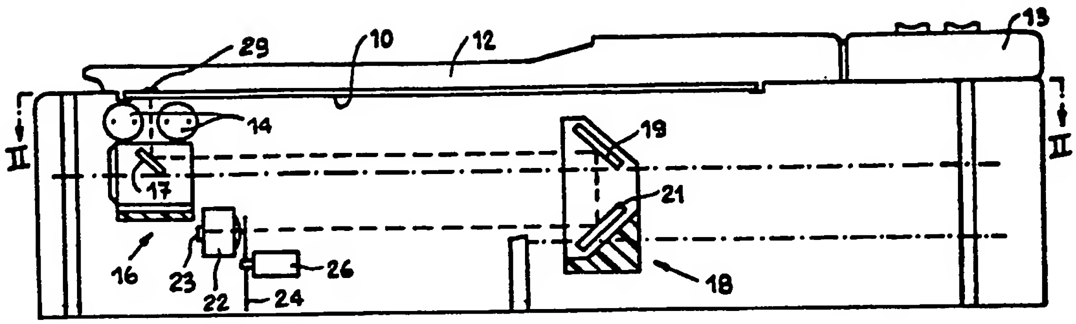
29
10
12
13
14
19
II
II
17
21
16
23
22
24
26
18

FIG.1

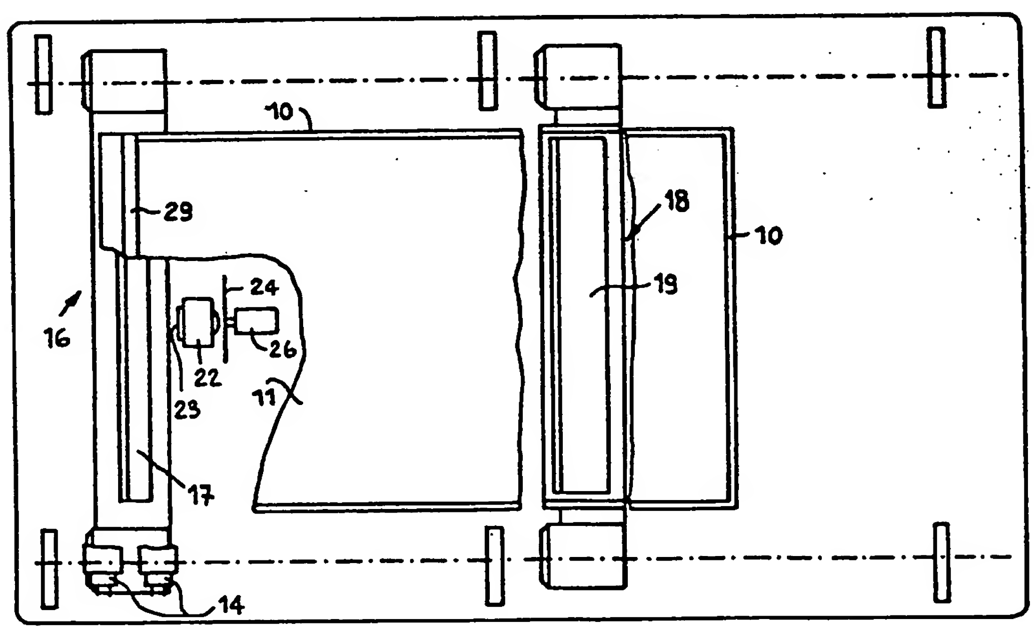
10
29
18
10
19
16
24
26
22
23
11
17
14

FIG.2

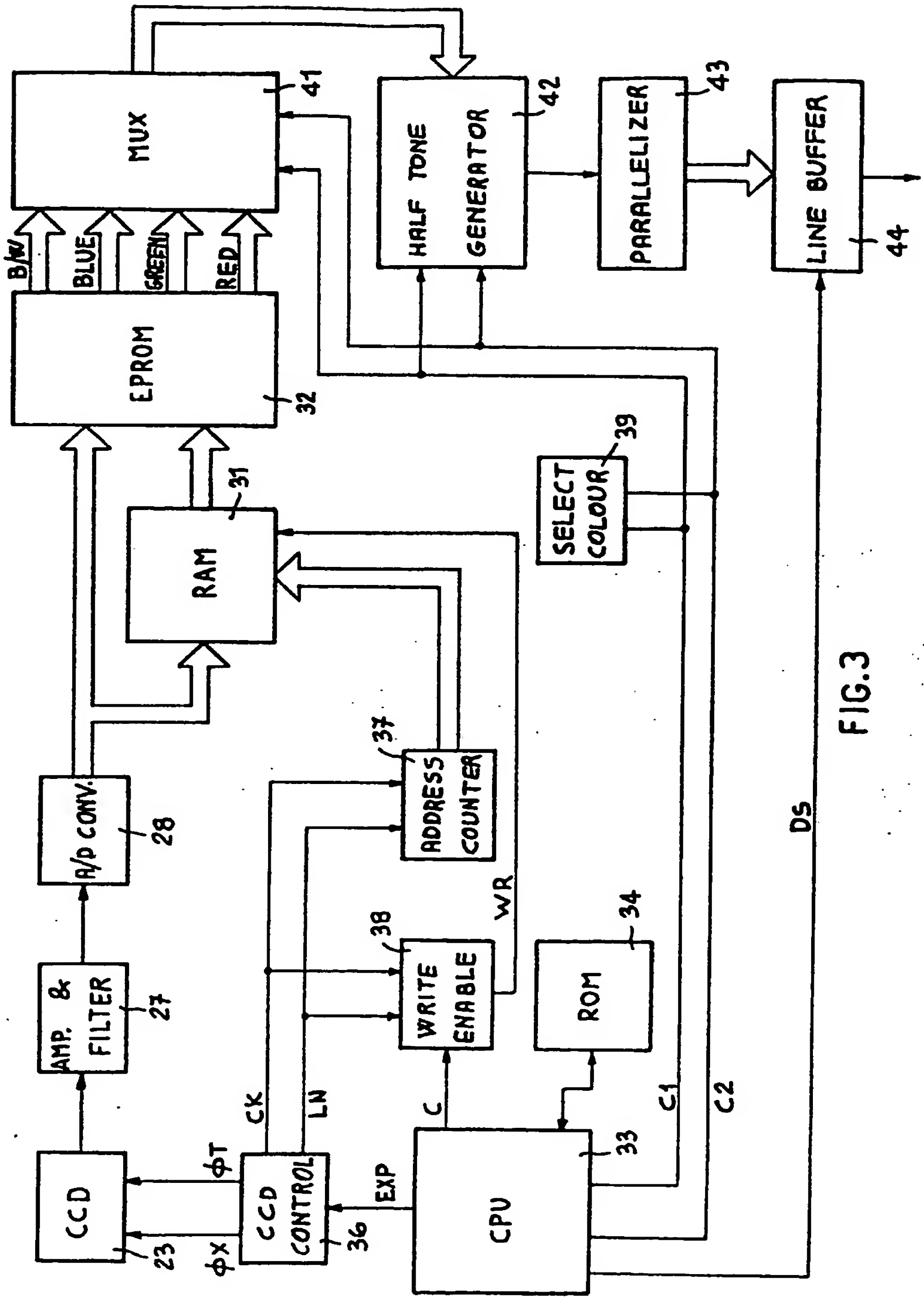
MUX
41
HALF TONE GENERATOR
42
PARALLELIZER
43
LINE BUFFER
44
B/W
BLUE
GREEN
RED
EPROM
32
RAM
31
SELECT COLOUR
39
A/D CONV.
28
AMP. & FILTER
27
ADDRESS COUNTER
37
WRITE ENABLE
38
WR
ROM
34
CCD
23
CCD CONTROL
36
CPU
33
ΦT
ΦX
CK
LN
EXP
C
C1
C2
DS

FIG.3

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